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Government subsidization and enterprise productivity: A comparative analysis of the steel and photovoltaic industries

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ABSTRACT

Government subsidies play a crucial role in optimizing industrial structures, eliminating outdated production capacities, and facilitating industrial transformation and upgrading in traditional industries. This paper is based on data collected from 112 sources, including 26 listed companies in China's steel industry and 30 companies in the photovoltaic sector, during the period from 2019 to 2020. Utilizing the three-stage undesirable output SBM model, we examine the impact of government subsidies on input-output slack and production efficiency. We find that the production efficiency of steel enterprises and photovoltaic enterprises is seriously polarized after considering the undesirable output, and the production efficiency of relatively small enterprises is high for the steel industry. In an unstable economic environment, it is advisable for the government to provide pre-subsidies to steel enterprises to assist them in adjusting resource allocation and effectively responding to unforeseen events. Regardless of the economic conditions, photovoltaic enterprises rely more on post-subsidies to mitigate personnel and technology investment slack. Overall, this study sheds light on the effectiveness of government subsidies in driving efficiency improvements in traditional and emerging industries.

1. Introduction

In 2020, China achieved a significant milestone as its gross domestic product (GDP) surpassed 100 trillion yuan for the first time, marking a notable success. However, China's economic development over the past four decades has primarily relied on an extensive growth model, which has had detrimental effects on the environment. Persistent environmental pollution and ecological degradation pose threats to China's path to sustainable development. Thus, the current stage of economic development prioritizes the transformation of the economic model, adjustment of the industrial structure, and promotion of clean energy development as key objectives for sustainable economic growth [1]. The operations of enterprises inevitably involve multiple stakeholders, with a close interrelation between enterprises and the government. To achieve the aforementioned objectives, the government plays a vital role by providing policy support, planning guidance, and short-term subsidies to expedite the transformation of industrial structures. Government subsidies refer to the financial support granted to enterprises through direct fund allocation and indirect relief measures, which alleviate financial constraints and promote enterprise development [2,3]. Signaling theory suggests that investors and relevant stakeholders can assess the government's future economic development direction based on the extent and pace of support provided to specific industries and enterprises. Government subsidies act as a positive signal to investors and stakeholders, demonstrating that the subsidized enterprises are acknowledged and supported by the government. Receiving government subsidies not only assists enterprises in addressing financial challenges, but also enhances their positive reputation. Consequently, enterprises actively seek government subsidies. Overall, the provision of government subsidies in China serves as a crucial instrument to facilitate the transition to a sustainable and environmentally friendly economy. By signaling government support, subsidies not only alleviate financial burdens for enterprises but also contribute to enhancing their overall image. This approach supports the broader goals of achieving ecological security, protecting the environment, and promoting sustainable economic growth. As such, government subsidies play a pivotal role in driving economic development and fostering cooperation between enterprises and the government [4,5].

Government subsidies, implemented through various mechanisms, have the potential to augment available funding for enterprises and

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alleviate their financial challenges. This, in turn, prompts companies to reevaluate their fund allocation strategies. The reallocation of funds not only directly impacts a company's production and innovation endeavors but also indirectly influences its overall production efficiency. Production efficiency, herein, refers to the relative relationship between resource input and output, serving as a reflection of a company's competitiveness. To a significant extent, efficiency plays a pivotal role in ensuring a company's survival and represents a paramount objective pursued throughout its developmental trajectory. However, it is essential to acknowledge that enterprises exhibit heterogeneity in terms of production efficiency. Companies that demonstrate high production efficiency tend to be more competitive, while those with lower efficiency face greater challenges. Consequently, the level of efficiency attained by a company significantly influences its ability to generate substantial income and sustain healthy development. Therefore, when enterprises receive various forms of government subsidies, both direct and indirect adjustments to their production efficiency are expected to occur.

However, the government, being an external entity to businesses, faces limitations in accessing comprehensive information regarding subsidy applications. Its knowledge of companies' operational conditions, research and development investments, and financial performance is often inadequate, leading to an informational disadvantage. Consequently, the government relies primarily on the application materials submitted by companies to determine the list of eligible recipients for subsidies. This informational constraint may result in the unintentional subsidization of companies with poorer conditions, giving rise to potential issues of adverse selection [6]. In such cases, government subsidies may not only promote industrial development but also disrupt industry stability. Another challenge stemming from information asymmetry is the problem of moral hazard. In their pursuit of securing government subsidies, company managers may be inclined to make certain choices. Firstly, after receiving funding from local governments, they may delay or withhold the disclosure of the company's true development status. Secondly, in order to secure sizable and long-term government subsidies, companies may adopt a speculative approach, prioritizing short-term gains over long-term planning and operational considerations. This dynamic creates a cycle where companies incentivize the government to increase subsidies. Furthermore, as companies expand their scale with the aid of government subsidies, they may exceed their optimal production capacity, leading to diminishing returns on investment, reduced efficiency, and the potential for overcapacity. Therefore, it is evident that the impact of government subsidies on businesses remains a contentious issue and has emerged as a prominent topic of discussion within the realm of domestic and international economic management.

Against the backdrop outlined above, this study endeavors to investigate the influence of government subsidies on production efficiency in both traditional and emerging industries, with a focus on enterprise productivity. Moreover, it seeks to examine how government subsidies empower efficiency at the micro-level. Guided by this overarching objective, the study aims to address the following research questions: 1) To what extent do government subsidies impact enterprise production efficiency, and is this impact positive or negative? 2) Are there variations in the effects of government subsidies on production efficiency among different types of enterprises? 3) Additionally, the COVID-19 pandemic, which commenced in January 2020, brought about significant socio-economic alterations and posed substantial challenges across industries. Therefore, do the effects of government subsidies on enterprise production efficiency remain consistent in diverse socio-economic environments? Through the investigation of these questions, this study seeks to advance our comprehension of the role played by government subsidies in enhancing enterprise efficiency under varying circumstances and offer valuable insights and recommendations for future policy formulation.

2. Literature review

In terms of original intent, government subsidies are intended to promote economic development, upgrade the industrial structure, and support emerging industries, to promote both social and corporate performance. But the emergence of practical problems such as market failures, government failures, and principal-agent problems has led to a bias in the effectiveness of government subsidies. Thus, the role of government subsidies has become a hot issue in the field of economic management at home and abroad. The existing literature generally studies from the following three perspectives. The first is the impact of government subsidies on corporate performance. Through empirical analysis of corporate data in the United States, Malaysia, South Korea, Italy, and other regions, foreign scholars have found that government subsidies have increased sales revenue, corporate value, and fixed assets of enterprises, which promote corporate performance to a considerable extent, and concluded that government subsidies have a positive effect on corporate performance [7–9]. At the same time, some domestic scholars also believe that government subsidies are positively correlated with corporate performance, that is, government subsidies have a significant role in promoting corporate performance [10–12]. However, some scholars have argued that government subsidies may induce moral hazard and rent-seeking, and lead to a negative impact of government subsidies on firm performance [13–16].

Second is the impact of government subsidies on enterprise innovation. As technological innovation has public goods properties and externalities, it is easy for other enterprises to imitate the innovation after the technological product is on the market [17], which means that enterprises cannot enjoy the full benefits of R&D, and results in a lack of incentive to continue innovating. At this point, the role of the market in the rational allocation of resources is ineffective. To compensate for the loss of earnings from technology spillovers, government intervention in R&D innovation is needed [18], while government subsidies can also alleviate the financial pressure on enterprises caused by excessive R&D capital investment. But, there are still inconsistencies in the findings of domestic and international scholars for the impact of government subsidies on enterprises' R&D investment. On the one hand, some scholars argue that government subsidies can compensate for enterprises' lost earnings and reduce technological innovation costs. Thus, government subsidies have a "crowding-in effect" on enterprises' R&D investment [19–22]. On the other hand, as government subsidies essentially distort the allocation of resources in the market and create a soft budget constraint, this leads to a large amount of private capital being squeezed out of the R&D investment of enterprises. Thus, government subsidies have a "crowding-out effect" on R&D investment [23–25]. In addition, some scholars argue that the relationship between government subsidies and R&D investment is non-linear and that there exists a threshold effect since inside the threshold is the "crowding-in effect", while outside the threshold there's the "crowding-out effect" [26–28].

The third is the introduction of moderating or mediating variables to explore the impact mechanism of government subsidies on firm performance and innovation [29–31]. Some scholars have also studied the impact of government subsidies on firm performance and innovation from the perspectives of internal corporate governance, market entry barriers, financing constraints, rent-seeking, and political connections [32–34]. Meanwhile, other scholars have studied the impact of government subsidies on enterprises' Total Factor Productivity (TFP). Similarly, there are two disputes about the impact of government subsidies on TFP: under the influence of different industries and different influencing factors, government subsidies play a role in improving the TFP of enterprises [35,36] or inhibitory effect [37,38].

Through an extensive review of the existing literature, it becomes evident that there is a substantial body of research on the role of government subsidies. However, these studies often predominantly consider the effect of subsidies on expected outputs, disregarding the implications of undesirable outputs such as overcapacity and resource redundancy that may arise due to subsidies. Consequently, the assessment of the effectiveness of government subsidies may be biased. Furthermore, while some scholars have explored the role of government subsidies from the perspective of total factor productivity, these studies fail to delve into the specific factor productivity of enterprises, particularly in terms of production efficiency. Thus, further investigation is warranted in order to comprehend how government subsidies impact firm factor productivity, particularly in relation to production efficiency. Presently, prevailing research methods in the existing literature mainly concentrate on regression analysis employing econometric models and game theory analysis, with relatively fewer studies utilizing alternative methods to evaluate the role of government subsidies.

In light of this, our study draws inspiration from these gaps and aims to adopt a dual perspective, encompassing both traditional and emerging industries. Additionally, we incorporate the analysis of undesirable outputs to construct an appraisal framework for firm production efficiency. We will employ a three-stage DEA model to assess the production efficiency of enterprises under different socioeconomic environments, and explore the mechanisms through which government subsidies, as an environmental factor, affect enterprises. By employing these selected research methods and adopting these perspectives, our study endeavors to fill the gaps in the existing literature and advance a comprehensive understanding of the impact of government subsidies on firm efficiency. Moreover, this study will be contextualized within the framework of a significant public health emergency, allowing us to provide valuable insights and recommendations for policy-making in similar scenarios.

3. Materials and methods

Data Envelopment Analysis (DEA), formally introduced in 1978 by the distinguished American operations researchers W. Cooper, A. Charnes, and E. Rhodes [39], diverges from conventional approaches to efficiency assessment. Functioning as a non-parametric tool for evaluating efficiency, DEA eliminates the need for a priori assumptions regarding the functional forms of production or utility functions. It directly employs observed values of input and output data to compute efficiency scores at the unit level, thereby circumventing biases that could arise from potential model assumptions. Concurrently, DEA accommodates multiple inputs and outputs, enabling the comparison of efficiencies among distinct enterprises operating at the same output level. This capability facilitates a more comprehensive evaluation of a unit's efficiency, such as that of a company. DEA offers numerous advantages in assessing relative efficiency and has evolved into one of the extensively employed methodologies in efficiency analysis, finding wide-ranging applicability across various domains of efficiency evaluation.

Since the traditional DEA model does not consider the influence of environmental factors and random errors, its results will be biased. To solve this problem, Fried et al. proposed a three-stage DEA model. The new model can not only eliminate the influence of environmental factors, to obtain more accurate and real production efficiency values, but also explore the influence of environmental factors on efficiency [40]. Therefore, this paper intends to use a three-stage undesirable output SBM model to measure the impact of government subsidies on the production efficiency of traditional and emerging industries. The specific calculation steps of three-stage undesirable output SBM model are as follows:

Stage 1: undesirable output SBM model production efficiency measurement

In the existing studies, the classical CCR and BCC models are often used in the DEA method. The traditional DEA models that estimate the efficiency of DMU from the radial and angle, without considering the slack of input variables and undesirable output variables, may deviate the final results from the actual. Thus Tone proposed non-radial and non-angular SBM models, which overcame the inherent defects of angle and radial measurement in traditional DEA models [41]. In addition, Tone constructs a new SBM model that includes "bad" output, namely the Undesirable SBM model, aiming at the phenomenon that "bad" output is inevitable in the production, operation, and production process of enterprises. The new model breaks the shackles of the traditional model that does not involve "bad" output and overcomes the shortcomings of the traditional radial and angle DEA model and can provide more accurate and realistic results [42]. The model is:

$$\rho^* = \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{i0}}}{1 + \frac{1}{s_1+s_2}\left[\sum_{r=1}^{s_1}\frac{s_r^g}{y_{r_0}^g} + \sum_{r=1}^{s_2}\frac{s_r^b}{y_{r_0}^b}\right]}$$
$$s.t.\begin{cases} x_0 = X\lambda + s^- \\ y_0^g = Y^g\lambda - s^g \\ y_0^b = Y^b\lambda + s^b \\ s^- \geq 0\ ,\ s^g \geq 0, s^b \geq 0, \lambda \geq 0 \end{cases} \tag{1}$$

In the equation, ρ^* represents the efficiency value of decision-making unit , m , s_1 , s_2, indicates the number of inputs, desired outputs and undesirable outputs respectively, x , y^g , y^b denotes input, desired output and undesired output respectively s^- , s^g , s^b denotes the slack variables for inputs, desired outputs and undesired outputs respectively. Slack variables are used to measure the deviation of each DMU from this optimal set. By analyzing the magnitude and direction of slack variables, we can determine which inputs or outputs act as bottleneck factors for the relative inefficiency of the DMU. This helps in assessing the improvement potential and optimization direction for DMUs; λ represents the weight vector. When $\rho^* = 1$, decision making units are efficient and on the production front , at this time , s^- , s^g , s^b are equal to 0; When $0 \leq \rho^* < 1$ represents the relative inefficiency of the decision-making unit and requires adjustments to input-output.

Stage 2: Adjustment of input-output data based on SFA model

In the first stage, the input-output slack variables analysed are jointly affected by external environmental factors, random errors, and internal management factors. In this stage, Fried et al. used the SFA model to eliminate the influence of environmental factors and random interference on efficiency measurement, and placed all decision-making units in the same environment [40]. The SFA model takes environmental variables as dependent variables and the slack value of input and output obtained in the first stage as independent variables to construct the following regression model:

$$S_{ik} = f(Z_k;\beta) + v_{ik} + \mu_{i_k} \tag{2}$$

$$S_{rk} = f(Z_k;\beta) + v_{rk} + \mu_{rk} \tag{3}$$

s_{ik}, s_{rk} are the slack value of input and output of the first decision-making unit, Z_k is the environmental variable, and parameter vector β is the unknown parameter to be estimated; $f(Z_k;\beta)$ represents the impact of environmental variables on input and output slack. $v_{ik} + \mu_{ik}$ is the joint error term, generally assuming that $v_{ik} \sim (0, \sigma_{vm}^2)$ and $\mu_{ik} \sim (0, \sigma_{\mu r}^2)$.

Then maximum likelihood estimation (MLE) is used to estimate the unknown parameters. And according to the research of Luo and Chen [18,19], we can estimate the statistical noise by the following formula:

$$E[v_{mi}|v_{mi} + \mu_{mi}] = s_{mi} - f(Z_k;\beta) - E[\mu_{mi}|v_{mi} + \mu_{mi}] \tag{4}$$

$$E[v_{ri}|v_{ri}+\mu_{ri}] = s_{ri} - f(Z_k;\beta) - E[\mu_{ri}|v_{ri}+\mu_{ri}] \quad (5)$$

Finally, the impact of random interference and environmental factors on efficiency measurement is eliminated, and the accurate input and output values under the same environmental conditions are obtained. The adjustment formula is as follows:

$$X_{mi}^{A} = X_{mi} + [\max(f(Z_k;\beta)) - f(Z_k;\beta)] + [\max(v_{mi}) - v_{mi}] \quad (6)$$

$$X_{ri}^{A} = X_{ri} + [\max(f(Z_k;\beta)) - f(Z_k;\beta)] + [\max(v_{ri}) - v_{ri}] \quad (7)$$

Stage 3: Adjusted input-output data undesirable output SBM model productivity measurement

The adjusted input-output and undesirable output data were used to replace the original data from the first stage. Then undesirable output SBM model is again used to measure the efficiency values of each decision unit. All enterprises are under the same environmental and luck parameters, so the evaluation results are relatively objective and accurate. The specific steps of the three-stage undesirable output SBM model are shown in Fig. 1:

4. Index system construction and data source

4.1. Index system construction

Input indicators. The production function of a commodity refers to the maximum number of commodities that can be produced by different combinations of existing capital and labor. Therefore, in a certain sense, production efficiency reflects the maximum output that can be obtained under different combinations of capital and labor. After sorting out and analyzing the existing literature, it is found that most input variables constructed in the existing literature follow the principle of the Cobb-Douglas production function. According to Cobb-Douglas production function, the input factors of enterprises should include labor factors, capital factors, and technical factors, which jointly determine the output level of enterprises. Since the whole production process of the enterprise involves many input indicators such as human, financial, and material resources, drawing on the existing literature on production efficiency [43,44], this paper selects the number of employees, net fixed assets, management costs, and the number of R&D personnel as input variables, which separately represent the labor level, capital level and technical level in each enterprise.

Output indicators. Output variables can be divided into two types: desirable output and undesirable output. The desirable output variables are the output that the company wants and desires, or the values created by the company's inputs, and are called the "good" output which is desired as big or as much as possible. Existing literature generally selects operating income, main business income, net profit and production, and so on as desirable output [45,46]. Therefore, in this paper, main business income and net profit are selected as the desired output variables.

The undesirable output which is opposite to desirable output refers to the output that the enterprise does not want to get, and is called the "bad" output. Since productivity levels continue to rise, the supply of products in various industries exceeds the demand, resulting in a degree of overcapacity as the actual output of enterprises is lower than their optimal scale of production. Severe overcapacity will seriously damage business efficiency, so this paper chooses the idle capacity of enterprises as undesirable output. This paper uses the method by Bai to calculate the capacity utilization rate of each enterprise and then uses (1− capacity utilization rate of enterprises) to obtain the idle capacity of each enterprise [47]. In addition to this, the resource allocation behavior of enterprises in the production process is susceptible to limited rationality, and enterprises will constantly adjust their production behavior according to the competitive behavior of the market, all these elements may lead to the transformation of the original primary production resources into the secondary production resources, result in resource accumulation and eventually lead to redundant resources [48]. Thus this paper chooses slack resources as another undesirable output. As slack resources can be divided into absorbed slack resources and unabsorbed slack resources, this paper focuses on the impact of government subsidies on productivity, which considers short-term redundant resources and mainly focuses on unabsorbed slack resources of enterprises. Unabsorbed slack resources are generally expressed in terms of the current ratio [49].

Environmental indicators. Environmental factors refer to the objective factors that affect the efficiency of enterprises but are not subject to the subjective control of enterprises, and which the enterprise cannot change or find it difficult to change in a short time. The selection of environmental variables should follow the principle that they will have a certain impact on all analysis objects but have different effects with different analysis objects. Generally, the selection of environmental variables mainly includes industry status, macro-environment or government industrial policy, and so on. Therefore, in this paper, government subsidies are selected as environmental variables. Due to the different time points of government subsidies, the effects on enterprise efficiency are also inconsistent. To better explore the impact of government subsidies on enterprise production efficiency, government subsidies in this paper are divided into two types, namely pre-subsidies

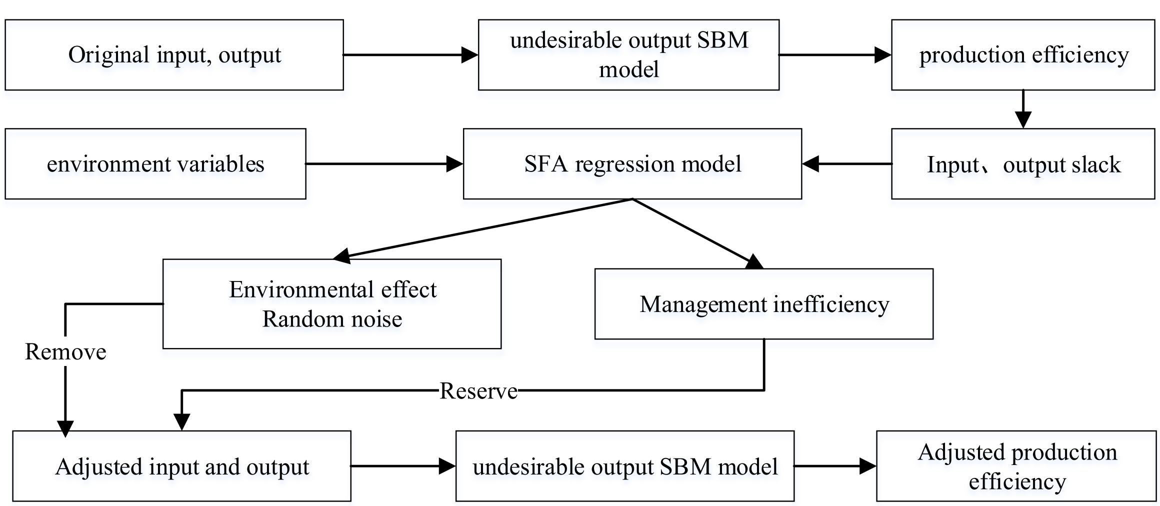

Fig. 1. Three-stage undesirable output SBM model specific steps.

and post-subsidies. Pre-subsidy is represented by the ratio of government subsidies to total assets obtained by the company, and post-subsidy is represented by the ratio of a tax return to total assets obtained by the company [50].

4.2. Data source

This paper intends to study the different impacts of government subsidies on the production efficiency of traditional industries and emerging industries. Therefore, this paper selects the steel industry and photovoltaic industry as representatives of traditional industries and emerging industries, and takes the black metal manufacturing enterprises and photovoltaic concept companies listed in the A-share market as the research objects. The reason why the steel industry and photovoltaic industry are selected as the research objects is as follows: the development environment of the steel industry has changed greatly after China's economic development entered a new normal. After the year 2015, China's steel production and consumption from the peak began to enter a downward trend, and the steel manufacturing industry began to enter an overall loss situation. Indeed, industrial development during this period went into hibernation. At the same time, the country promoted supply-side structural reform and introduced fiscal policies to manage overcapacity in the steel industry, to help the steel industry to adjust and optimize its industrial structure. Meanwhile, in response to the negative impact of the 2008 US financial crisis and the challenges posed by the new industrial revolution, Premier Wen Jiabao stressed the importance of developing strategic emerging industries at three symposiums on the development of new and strategic industries in 2009. From that point forward, as a typical representative of strategic emerging industries, photovoltaic enterprises have been developing rapidly with the support of the government. However, in recent years, photovoltaic enterprises have experienced weak independent R&D capability and overcapacity. Therefore, both the steel industry and the photovoltaic industry are receiving varying degrees of government subsidies, while these companies are also growing under the influence of government subsidies.

Therefore, this paper makes use of the CSMAR database and the financial data of steel enterprises and photovoltaic companies. Based on principles such as the availability of indicator data, listed companies with missing financial data and abnormal indicators were excluded; companies that no longer belonged to the above industries after ST, *ST, restructuring or change in main business were excluded; companies listed later than the research window period were excluded, and listed companies with negative net profit in the indicators were excluded. Finally, a total of 26 listed companies in the steel industry and 30 listed companies in the photovoltaic industry with a total of 112 data samples from 2019 to 2020 were selected for the study.

5. Empirical analysis

The production efficiency of the steel industry and photovoltaic industry in the first and third stages of 2019–2020 is calculated by using MATLAB software (the results are shown in Table 1). The dependent variables in the second stage SFA regression analysis are the input and output slack variables of the decision unit in the first stage output, and the independent variables are the environmental variables, relying on Frontier 4.1 software for the calculation (see Table 2 and Table 3).

5.1. Production efficiency calculation results and analysis

From the results of the first stage (see Table 1), the average production efficiency of China's steel enterprises in 2019 and 2020 is 0.6938 and 0.6683. After eliminating the interference of environmental and random errors, the actual and adjusted production efficiency in the third stage is 0.6247 and 0.6687. It can be concluded that from the perspective of the whole industry, government subsidies in normal years have improved the production efficiency of steel enterprises. After the occurrence of emergencies, government subsidies to a certain extent

Table 1

Comparison of production efficiency between steel industry and photovoltaic industry before and after adjustment (2019–2020).

	Before (steel)		After (steel)			Before (photovoltaic)		After (photovoltaic)	
DMU	2019	2020	2019	2020	DMU	2019	2020	2019	2020
000709	1.0000	0.2979	1.0000	0.3087	002079	0.3128	0.2542	1.0000	1.0000
000717	1.0000	1.0000	1.0000	1.0000	002129	0.0410	0.5333	0.0702	0.5016
000761	0.2096	0.2224	0.2645	0.2644	600089	1.0000	1.0000	1.0000	1.0000
000778	0.2990	0.5515	0.3278	0.4775	600295	0.6066	0.3928	0.6623	0.4187
000825	1.0000	1.0000	1.0000	1.0000	600438	1.0000	1.0000	1.0000	1.0000
000898	1.0000	0.5406	1.0000	0.6348	601012	1.0000	1.0000	1.0000	1.0000
000932	1.0000	1.0000	1.0000	1.0000	601908	0.2269	0.3326	0.4855	0.4417
000959	1.0000	1.0000	1.0000	1.0000	603185	0.2658	1.0000	1.0000	1.0000
002075	0.4864	1.0000	1.0000	1.0000	002056	0.3676	0.3126	0.4231	0.4269
002318	0.5076	0.6231	0.1169	1.0000	002218	0.1681	0.1934	0.6024	0.4762
002443	1.0000	1.0000	0.1377	0.4698	002459	0.5015	0.4362	0.4382	0.4257
002478	0.5104	0.1958	0.1025	0.3051	300117	1.0000	0.2918	1.0000	1.0000
600010	0.2279	0.1710	0.2807	0.1800	300118	1.0000	0.2087	0.7256	0.2518
600019	1.0000	1.0000	1.0000	1.0000	300316	1.0000	0.7064	1.0000	1.0000
600022	0.3564	0.4615	0.4038	0.4362	300393	0.4118	0.3134	0.5893	0.5020
600126	1.0000	1.0000	0.3756	0.6811	300724	1.0000	1.0000	0.9737	1.0000
600231	0.3910	0.4800	1.0000	0.5033	600151	1.0000	0.2567	0.8478	0.2568
600282	1.0000	1.0000	0.6301	0.8837	601865	1.0000	1.0000	1.0000	1.0000
600295	0.1551	0.3066	0.1776	0.3073	601877	0.6987	1.0000	0.6970	1.0000
600307	0.4194	0.2752	0.4352	0.2990	603396	0.2562	0.2882	1.0000	1.0000
600507	1.0000	1.0000	0.3613	1.0000	603806	1.0000	1.0000	1.0000	1.0000
600569	0.1080	0.1900	0.2199	0.2479	000591	1.0000	1.0000	1.0000	0.6488
600782	1.0000	1.0000	1.0000	1.0000	002335	0.3313	0.2564	0.5569	0.4834
600808	0.3687	0.6487	0.4089	1.0000	002518	0.4282	0.3235	0.6702	0.5602
601003	1.0000	1.0000	1.0000	1.0000	300274	1.0000	1.0000	1.0000	1.0000
603878	1.0000	0.4124	1.0000	0.3884	300490	0.2535	0.0850	1.0000	0.4726
Mean	0.6938	0.6683	0.6247	0.6687	600770	0.2040	0.2237	1.0000	0.3375
					601222	0.3165	0.4125	0.4474	0.5144
					603063	1.0000	1.0000	0.7396	0.6446
					603507	0.2014	0.1889	0.3566	0.3531
					Mean	0.6197	0.5670	0.7762	0.6905

Table 2
SFA regression results of steel enterprises (2019–2020).

	Input redundancy (dependent variable)				Insufficient output (dependent variable)			
2019	Employee	Assets	Expense	R&D	Profit	Income	Idle capacity	Slack
constant	−562***	−3911529900***	−111502590***	26***	−623241730***	−2012347500	−0.01***	−0.17
Prior	−317619***	−444269890000***	−12959037000***	−28961***	9855702800***	−23668024000***	−16.73***	−2.82***
Post	−253740***	−307131700000***	−13558993000***	−11880***	36831573000***	173838910000***	3.55***	21.48***
σ^2	66479349***	20344483000000000000***	216537440000000000***	631105***	1293386100000000000***	851704960000000000***	0.13***	0.21***
γ	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***
LR	11.91***	11.91***	10.01***	18.87***	9.65***	11.91***	14.20***	21.97***
2020	**Employee**	**Assets**	**Expense**	**R&D**	**Profit**	**Income**	**Idle capacity**	**Slack**
constant	299***	−11336691000***	−98575627***	−70***	−4568484***	−3823971800***	0.00	−0.39
Prior	−842817***	−2142394300000***	−26739957000***	−60916***	−164045110000***	270269710000***	−20.39***	−2.19
Post	30384***	300519310000***	2105370100***	18633***	5578433900***	−42710921000***	1.9***	28.68***
σ^2	78749388***	86274061000000000000***	161424170000000000***	444344***	2188688300000000000***	2626621500000000000***	0.16***	0.6646
γ	1.00***	1.00***	1.00***	0.99***	1.00***	1.00***	1.00***	1.00***
LR	11.16***	12.73***	11.91***	10.01***	11.91***	13.13***	9.99***	15.87***

Note: $\boldsymbol{\sigma}^2$ is the combined error term covariance, $\boldsymbol{\gamma}$ is the share of management inefficiency variance and LR is the likelihood ratio. *, **, *** denote passing the significance test at the 10%, 5%, and 1% levels, as below.

Table 3
SFA regression results of photovoltaic enterprises (2019–2020).

	Input redundancy (dependent variable)				Insufficient output (dependent variable)			
2019	Employee	Assets	Expense	R&D	Profit	Income	Idle capacity	Slack
constant	−2114***	−463014330***	−22445172***	−55***	−324268480***	−1734655500***	−0.01***	−0.02***
Prior	181188***	−156545160000***	−2095369300***	2507***	−28767100000***	−32680710000***	−5.69***	6.13***
Post	−18033***	−42630747000***	−734525230***	878***	19876023000***	−11336427000***	1.21	−9.78***
σ^2	10978816***	20677677000000000000***	153067670000000000***	242891***	298526970000000000***	1122161400000000000***	0.18***	0.43***
γ	0.96***	1.00***	1.00***	1.00***	0.91***	1.00***	1.00***	1.00***
LR	9.45***	13.74***	13.74***	16.04***	7.19***	15.61***	16.21***	31.86***
2020	**Employee**	**Assets**	**Expense**	**R&D**	**Profit**	**Income**	**Idle capacity**	**Slack**
constant	−2578***	−2137117400***	−71483223	−309***	−470560090***	−640958530***	−0.01	−0.0007
Prior	234227***	−70330816000***	−330241940***	17669***	−25270259000***	37928607000***	−0.05	0.1075
Post	30712***	−630885220***	81535984***	662	26883231000***	−3568832900***	0.25	−0.1153
σ^2	8185244***	3322520300000000000***	342416350000000000***	307790***	660627680000000000***	575514880000000000***	0.18***	0.5062***
γ	0.83***	1.00***	1.00***	1.00***	0.93***	1.00***	1.00***	1.00***
LR	5.00*	13.74***	13.74***	10.14***	6.99***	14.69***	15.61***	33.04***

maintain the stability of the steel industry and provide a guarantee for the sustainable and safe production of enterprises. In addition, according to Table 1, the industry average for both pre- and post-adjustment productivity is less than 0.7, which means there is still a lot of room for improving productivity in the steel industry. At the same time, the distribution of production efficiency value in the steel industry presents an extreme polarization state, and the production efficiency value gap is very large. The efficiency value of most non-DEA efficient steel enterprises is lower than 0.5 and results in a serious lag in production efficiency. The fact that different steel enterprises have a large gap in the means of production, results in the distribution of industry resources being inclined toward the strong large steel enterprises. Therefore, how to narrow the gap between the production efficiency of steel enterprises and promoting common development is a challenge faced by the steel industry.

From the micro-analytical point of view, more than 12 steel enterprises were in an invalid DEA efficiency state, including 9 strong, large-scale steel enterprises in 2019. However, after excluding the influence of government subsidies and random interference, DEA efficiency is significantly improved, indicating that government subsidies may have a negative impact on large steel enterprises. Conversely, the three relatively small steel enterprises had significantly higher DEA efficiencies after removing the effects of government subsidies and random disturbances. This suggests that access to government subsidies boosts the productivity of the relatively small steel enterprises. Relatively speaking, the productivity of each steel company in 2020 shows a different picture. 7 strong steel enterprises show no change in productivity and remain DEA efficient. 4 companies show a rapid decrease in productivity due to the COVID-19 environment, while the remaining 15 steel enterprises show an increase in productivity values to varying degrees. As a fundamental industry and the most important basic industrial sector, the steel industry is relatively unaffected by public health emergencies. The trend in productivity values for steel enterprises in the adjusted 2020 timeframe is relatively consistent with the trend in productivity values for steel enterprises in the adjusted 2019 period. Therefore, government subsidy policies for the steel industry should fully differentiate between enterprises of different sizes and target subsidies to steel enterprises of different sizes.

The distribution of efficiency values in the first and third stages of China's photovoltaic industry is very different from that of steel enterprises. In 2020, the production efficiency value of 13 photovoltaic enterprises was lower than that in 2019, accounting for 43.33% of the number of research enterprises. Affected by domestic COVID-19, the prices of some products located in the upstream industrial chain, such as battery chips, silicon materials, and components, also began to decline. Under the combined effect, these enterprises' production efficiency declined. Most enterprises are relatively smaller in scale and have limited experience in dealing with emergencies. The production efficiency values of 17 enterprises remain unchanged or increased, accounting for 56.67% of the number of research enterprises. On the one hand, according to the original data, most enterprises whose production efficiency value keeps increasing or remains unchanged have large scale, strong strength, and sufficient resources to take measures to deal with unexpected risks; on the other hand, the outbreak time of COVID-19 is inconsistent at home and abroad. The domestic market of the photovoltaic industry is mainly affected by COVID-19 in the first quarter of 2020. At the same time, as a big exporter of photovoltaic products, China's overseas market share is relatively high, but the outbreak time of COVID-19 in foreign countries was at the end of March 2020, and, since China had returned to normal production, the relative impact was small. Compared with before, there are 14 enterprises whose production efficiency declined in 2020 after the adjustment, accounting for 46.67% of the number of research enterprises. The production efficiency values of 16 enterprises remain unchanged or increased, accounting for 53.33% of the number of research enterprises. The change of the efficiency value after the adjustment is not much different from that before the adjustment, so no detailed analysis is made.

The average production efficiency of photovoltaic enterprises in China in 2019 and 2020 is 0.6197 and 0.5670. After eliminating the interference of environmental and random errors, the actual production efficiency adjusted in the third stage is 0.7762 and 0.6905. According to the results, the average production efficiency of photovoltaic enterprises adjusted in 2019 and 2020 is greater than before. This shows that government subsidies reduce the production efficiency of photovoltaic enterprises to a certain extent. For photovoltaic power generation, the technical support and capital level are relatively high, but the immature technology and the reduction of downstream power demand cause serious overcapacity in enterprises. To pursue achievements and support the development of emerging industries, the government gives a lot of policy tilt and financial support to photovoltaic enterprises. Meanwhile, to obtain financial support, photovoltaic enterprises pay attention to short-term benefits in the investment and construction of new projects and find it easy to make blind investment decisions. Therefore, for emerging industries with unstable production and operation environment or immature technology, government subsidies should be appropriately channeled to guide enterprises to promote the industrial chain of core technology.

5.2. Second stage: empirical results of SFA model

The results and analysis of the first stage show that the role of government subsidies for traditional industries and emerging industries are very different. Next, this paper will focus on the analysis of the role of government subsidies as environmental factors in the steel industry and photovoltaic industry. The SFA slack measurement results of input-output of steel enterprises and photovoltaic enterprises in 2019 and 2020 are shown in Tables 2 and 3. According to Tables 2 and 3 and it can be seen that the environmental variables of pre-subsidy and post-subsidy stages of government subsidies have an impact on the input and output slack variables of steel enterprises and photovoltaic enterprises. Firstly, when the regression coefficient γ in the SFA measurement results is positive, increasing environmental variables will lead to an increase in input redundancy and output insufficiency, resulting in a waste of resources and a decrease in efficiency. When the regression coefficient γ is negative, increasing environmental variables will help reduce input redundancy and insufficient output, which will reduce waste, increase output and improve efficiency. When γ is close to 0, the random disturbance term may be the main reason for input redundancy and insufficient output; when γ is equal to 0, the OLS regression is directly used at this time, and the SFA method is unnecessary; when γ is close to 1, the external environmental factors are dominant, and the influence of external environmental factors leads to insufficient output and redundant input. Therefore, it is necessary to adopt the SFA model according to the results. It can also be seen from Tables 2 and 3 that the values of slack variables of steel enterprises and photovoltaic enterprises in 2019 and 2020 are relatively high, which are basically close to 1, and both have passed the significant indigenous test at the level of 1%. The LR values of each likelihood ratio have passed the significant indigenous test at the level of 1%, indicating that the government's pre-subsidy and post-subsidy decisions have significant indigenous effects on efficiency.

5.2.1. Analysis of SFA results for steel enterprises

According to the SFA regression results of steel enterprises in Tables 2 and it can be concluded that in 2019 and 2020, the regression coefficients of the slack variables of the government's pre-subsidy on the labor, capital, and technical inputs of steel enterprises are negative, and has passed the 1% level of significance test, which shows that both before and after COVID-19, the increase in government subsidies has contributed to a reduction in the number of staff, net fixed assets, management costs and the number of R&D personnel invested. It shows that the increase of government subsidies whether in advance or after, will have a positive impact on the increase of enterprise efficiency. The regression coefficients of the slack variables of the government's post-subsidy on the input of steel enterprises in 2019 are negative, indicating that increasing the government's post-subsidy is helpful to reduce the input slack. On the contrary, in 2020 after COVID-19, the regression coefficient of government post-subsidy to input slack variables is positive, which indicates that increasing post-subsidy will lead to increase input slack and waste of input resources. Therefore, compared with post-subsidy, pre-subsidy can reduce the waste of resources and maintain the smooth operation of steel enterprises.

The government's pre-subsidy has a positive effect on the slack variable of net profit in the expected output of steel enterprises and a negative effect on main operating income in 2019 and the opposite in 2020, which both pass the 1% level of a significance test and indicate that pre-subsidy is not conducive to an increase in net profit for steel enterprises in normal years and can even cause a loss in net profit for enterprises to some extent. After the occurrence of COVID-19, the government's pre-subsidy is conducive to steel enterprises to make adequate preparations for emergencies, to avoid reducing the net profit of enterprises. For steel enterprises belonging to the traditional industry, the government's pre-subsidy is conducive to increasing the main business income. But in the aftermath of COVID-19, downstream demand has decreased, and pre-subsidy by the government may result in greater waste of resources. Therefore, during the COVID-19 period, the government's pre-subsidy is not conducive to increasing the main business income of enterprises. The effect of ex-post government subsidies on the slack variable of desired output of steel enterprises in 2019 is positive and passes the 1% level of a significance test. The reason may be that the post-subsidy has a certain time lag effect and some wrong decisions will be made by enterprises in utilizing resources to obtain ex-ante subsidies, which will lead to a reduction in net profit and main business income. However, after COVID-19, while the effect of post-subsidy on net profit slack for steel enterprises remains positive, the effect on main business income slack turns positive. This suggests that the government's post-subsidy helps to compensate for the steel enterprises'losses during the epidemic, thereby mitigating the tendency to widen the slack in main operating income.

According to Table 2, the impact of prior government subsidies in 2019 on the slack of idle enterprise capacity and resources in the undesirable output of steel enterprises was negative, which passed the 1% level of significance test in 2019. This suggests that pre-subsidy can have a negative impact on the undesired output of steel enterprises. The post-subsidy of the government in 2019 and 2020 has a positive impact on the slack capacity and resource redundancy of idle enterprises in the undesirable output of steel enterprises, which has passed the test of 1% significance. It shows that the increase of post-subsidy will promote the rational allocation of resources in steel enterprises, reduce the existence of idle capacity, and promote the reduction of undesirable output. Therefore, to curb the behavior of enterprises that are bent on catering to the government in exchange for subsidies, post-subsidy should be adopted to promote the healthy development of enterprises.

5.2.2. Analysis of SFA results of photovoltaic enterprises

Based on the SFA regression results for photovoltaic enterprises in Tables 3 and it can be concluded that the regression coefficients of government pre-subsidy on net fixed asset slack and overhead slack for photovoltaic enterprises in 2019 and 2020 are negative and pass the 1% significance level test, indicating that government pre-subsidy help to reduce overhead as well as the reduction in net fixed asset input redundancy for photovoltaic enterprises. At the same time, the regression coefficients of the government's pre-subsidy on the slack variables of employee input and R&D staff input of photovoltaic enterprises is positive and passes the 1% significance level test, indicating that the government's pre-subsidy as a policy increases the number of redundant employees as well as a research staff of photovoltaic enterprises. The regression coefficient of government post-subsidy on the number of employees, net fixed assets, and overhead of photovoltaic enterprises in 2019 was negative and passed the 1% significance level test, indicating that increasing government post-subsidy was helpful to reduce input slack in human and capital factors of photovoltaic enterprises. Post-subsidy increases the input slack of researchers maybe because the mobility of researchers is relatively low for enterprises. In 2020, post-government subsidies only have a negative impact on input redundancy in net fixed assets and a positive impact on input slack in the number of employees, overhead, and R&D staff, and all pass the 1% level of a significance test. In the COVID-19 environment, post-government subsidies help to reduce the investment in fixed assets and the investment pressure on enterprises, while increasing the chances of rent-seeking in both directions by government enterprises.

For desirable output, the regression coefficients of 2019 prior government subsidies to the slack variables of net profit and main business income were negative, and both passed the 1% level of a significance test. This shows that government subsidies in advance can reduce under-output and increase output. However, after the occurrence of COVID-19 in 2020, the impact of the government's pre-subsidy on the main business income has turned negative. This may be related to the government's demand for enterprises to shut down after the occurrence of COVID-19. The impact of the government's post-subsidy on the net profit slack of photovoltaic companies in 2019 was positive and the impact on the main business income slack was negative and both passed the 1% level of a significance test. The government's post-subsidy has a significant impact on the solvency of the companies, but will also have some negative impact on the net profit of the companies because the amount of post-subsidy is not continuous. And according to Tables 3 and it can be seen that the government's post facto subsidy has a more significant impact on the net profit slack variable after COVID-19 occurs.

According to Table 3, the government's pre-subsidy in 2019 and 2020 has a negative impact on the slack of idle capacity of photovoltaic enterprises, indicating that increasing the pre-subsidy of enterprises will increase the idle capacity of enterprises and is not conducive to the full utilization of production resources. The government's prior subsidy has a negative effect on the resource redundancy of enterprises, which indicates that the prior subsidy can reduce the resource redundancy of enterprises and allocate resources rationally. But COVID-19 affects the stability of the data so that the impact of government pre-subsidy on idle resources and slack resources of enterprises in 2020 does not pass the significant indigenous test. However, the post-subsidy of the government in 2019 and 2020 has a positive impact on the relaxation of the idle capacity of photovoltaic enterprises, and a negative impact on the slack of resources, which is contrary to the impact of pre-subsidy on slack productivity and slack resource slack in idle enterprises. The government's post-subsidy can promote the effective use of idle production capacity of enterprises, but at the same time, it can also make the current capital and other resources of enterprises fail to play a full role, to a certain extent, resulting in a certain amount of idle resources.

6. Conclusion and outlook

6.1. Research conclusion

This paper introduces a novel concept of enterprise idle capacity and resource redundancy as undesirable outputs. It utilizes a three-stage undesirable output SBM model to calculate the production efficiency of 26 listed companies in the steel industry and 30 listed companies in the photovoltaic industry during the period from 2019 to 2020, discusses the impact of government subsidies as an environmental factor on traditional industries and emerging industries, and compares the impact of government subsidies before and after subsidies on the production efficiency of enterprises in the context of the COVID-19. The findings reveal several key points:(1) for steel enterprises and photovoltaic enterprises, the production efficiency calculation considering the undesirable output of enterprises would make the calculated production efficiency value lower; however, from the overall distribution, the production efficiency between different enterprises shows a serious polarization trend. (2) And based on the results, it can be concluded that companies with a small production scale have relatively high production efficiency. Therefore, how to allocate resources rationally and reduce waste is a major concern for large steel enterprises as well as for photovoltaic enterprises. (3) In the normal production year, and the COVID-19 situation, government subsidies as environmental factors also have great differences in the role of traditional industries and strategic emerging industries. For example, in the aftermath of COVID-19, the government should subsidize steel enterprises in the form of pre-subsidy to help them better respond to emergencies. Regardless of whether COVID-19 occurs, for photovoltaic companies to reduce personnel and technology input slack is more dependent on post-subsidy.

Overall, this study provides valuable insights into the intricate relationship between government subsidies and production efficiency in the steel and photovoltaic industries. It underscores the significance of effective resource allocation and waste reduction strategies. Moreover, the research sheds light on the diverse effects of subsidies on different industry sectors, particularly in response to the environmental factors imposed by the COVID-19 pandemic. Consequently, this research not only contributes to our understanding of production efficiency, but also offers valuable insights for policymakers and industry practitioners seeking to optimize resource utilization and promote sustainability in these critical sectors. Although our study was conducted within the framework of government subsidies in China, the subject bears universal relevance and impact on a global scale. Through an in-depth comprehension of the motivating factors, execution modalities, and consequences of China's subsidy strategies, foreign readers can assimilate experiential insights for the purpose of benchmarking and enhancing their own domestic subsidy frameworks. Furthermore, our research provides a pertinent exemplar for the global scholarly community, delineating the ramifications and intricacies associated with sector-specific fiscal incentives under specific policy paradigms. This holds illuminating significance for scholars engaged in the domains of economics, political science, and public administration.

6.2. Policy recommendation

Government providing subsidies to enterprises is not to deny or interfere with the decision-making of enterprises, but rather to mainly support the growth of enterprises, and support the development of the industry. However, to enhance local performance, officials seek rents and other reasons, so that government subsidies may appear to go against the laws of the market, pursue short-term interests and interfere directly with enterprises. Although government intervention has many shortcomings, it is undeniable that government subsidies not only promote the transformation and upgrading of traditional industries, optimize the industrial structure and eliminate backward production capacity, but also promote the rapid development of emerging industries.

To fully maximize the impact of government subsidies, it is imperative to implement comprehensive oversight throughout the subsidy process. Firstly, the establishment of a scientifically-based performance evaluation system can facilitate objective assessments of subsidy effectiveness. Secondly, subsequent evaluation and supervision of the allocation of government subsidy funds are also essential. Through rigorous supervision of the entire process, from subsidy application to utilization, we can ensure that government subsidies are effectively utilized. For instance, the government can establish an autonomous institution or committee dedicated to monitoring government subsidies. This body would conduct regular evaluations of subsidized projects undertaken by businesses, while providing transparent information to the public. Moreover, collaborative partnerships between the government and businesses could be forged to establish guiding principles and detailed guidelines for subsidy programs, ensuring that the utilization of funds remains aligned with public interests.

Furthermore, external evaluation agencies could be engaged to conduct independent assessments of subsidy programs. This approach would yield impartial evaluation results that serve as valuable references for government decision-making. Public participation in the supervision and evaluation of subsidy projects would also ensure that government funds are channeled towards areas of utmost need, thereby benefiting both businesses and society.

In conclusion, government subsidies play a pivotal role in promoting enterprise development and industry advancement. To fully exploit their potential, the establishment of a scientifically-grounded performance evaluation system, together with comprehensive supervision and evaluation, is necessary. This approach guarantees that government subsidies are efficiently utilized, while upholding the normal functioning of market mechanisms.

6.3. Future research

This paper contributes to the existing literature on government subsidies in the following ways. Firstly, it enhances the reliability of measuring the production efficiency of steel enterprises and photovoltaic enterprises by incorporating idle resources and resource redundancy as undesirable outputs in the efficiency model. This inclusion ensures more accurate efficiency results. Secondly, the study differentiates government subsidies into pre-subsidies and post-subsidies, and examines their impact on the input-output slack of steel enterprises and photovoltaic enterprises. This analysis clarifies the role of different forms of government subsidies in different industries. Lastly, utilizing sample data under normal economic conditions and the COVID-19 situation, the study explores the distinct effects of various government subsidies on different industries in different environments. In conclusion, this study has made substantial contributions to the field of government subsidies by not only providing empirical evidence for the formulation and optimization of subsidy policies, but also deepening our understanding and expanding the application scope of such subsidies. The research findings offer significant guidance to business managers, enabling them to accurately assess and leverage government subsidies while optimizing resource allocation and enhancing production efficiency. Furthermore, this study presents a framework for further exploration of the mechanisms by which government subsidies impact different industries and environments, thereby serving as a valuable reference for future theoretical research. Overall, the research outcomes of this paper hold practical implications and academic significance for businesses, governments, and the wider academic community, offering valuable insights for the advancement and decision-making processes in related fields.

The paper also has certain limitations. Firstly, the selected data only covers the years 2019–2020 for the steel and photovoltaic industries, and is limited to research data from publicly listed companies. The relatively small sample size may introduce certain deviations in the results. To obtain more comprehensive and accurate conclusions, future research could include data from additional sources and consider other relevant factors in the analysis. Secondly, this study focuses on the steel and photovoltaic industries, but other industries may have different subsidy policies and influential factors. To gain a broader understanding, future research could expand the scope by comparing variations across different industries. Furthermore, this paper employs the traditional data envelopment analysis method to calculate enterprises' capacity utilization. Although this method has been widely recognized by most scholars, there may still exist certain errors in the obtained capacity utilization due to the diversity in indicator selection. Therefore, in future research, consideration should be given to alternative methods for calculating capacity utilization to enhance the accuracy of the estimation. Lastly, this study primarily focuses on the government subsidy policies and industry development before and after COVID-19, but the time span is limited. To gain a better understanding of the long-term effects of subsidy policies on the industry, future research could incorporate data from a more extended period.

Credit author statement

Bing Qi: Conceptualization, Methodology, normal analysis, investigation, resources, data curation; writing—original draft preparation, writing—review and editing, project administration; funding acquisition. **Zhilin Yang:** Conceptualization, resources, writing—review and editing, supervision. **Tianjuan Deng:** Conceptualization, resources, writing—review and editing, supervision

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix 1. Acronyms Reference Appendix

Acronyms	Acronym Explanation
COVID-19	Coronavirus Disease 2019
TFP	Total Factor Productivity
DEA Model	Data Envelopment Analysis Model
DMU	Decision Making Units
CCR Model	Charnes, Cooper, and Rhodes, it is the fundamental model of DEA
BCC Model	Banker, Charnes, Cooper, it is the fundamental model of DEA
SBM DEA Model	Slacks-Based Measure Data Envelopment Analysis Model
SFA Model	Stochastic Frontier Analysis Model
OLS regression	Ordinary Least Squares regression

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